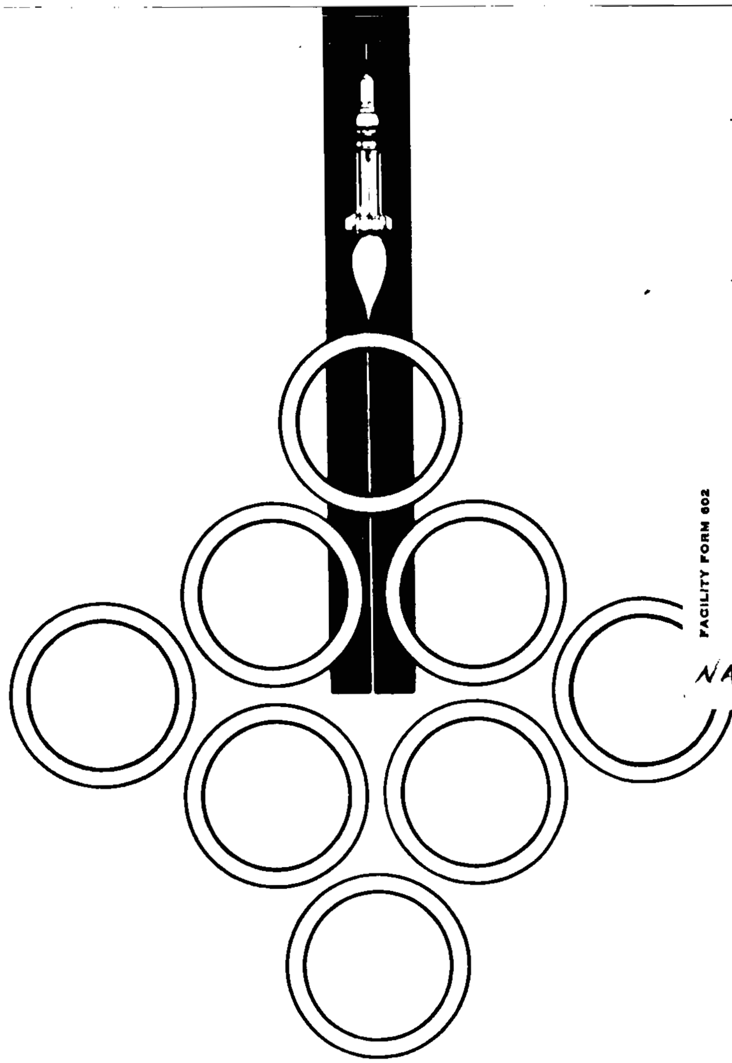

ENGINEERING DEPARTMENT

TECHNICAL MANUAL

SDES-64-414

Saturn I

LAUNCH VEHICLE SA-8
AND LAUNCH COMPLEX 37B
FUNCTIONAL SYSTEMS DESCRIPTION

Volume IX

RL10A-3 ENGINE AND HYDRAULIC SYSTEM FUNCTIONAL DESCRIPTION, INDEX OF FINDING NUMBERS, AND MECHANICAL SCHEMATICS

SPACE DIVISION CHRYSLER CORPORATION

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VOLUME IX
RL10A-3 ENGINE AND HYDRAULIC SYSTEM FUNCTIONAL DESCRIPTION, INDEX OF FINDING NUMBERS, AND MECHANICAL SCHEMATICS

MAY 1964

CHRYSLER CORPORATION SPACE DIVISION - NEW ORLEANS, LOUISIANA

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FOREWORD

This volume is part of a ten-volume set that describes the mechanical and electromechanical systems of launch vehicle SA-8 and launch complex 37B that function either during the prelaunch countdown or in the event of a launch abort. The mechanical and electromechanical systems of the launch vehicle that function during flight are also described.

The ten-volume set is prepared for the Functional Integration Section, Systems Integration and Operations Branch, Vehicle Systems Division, P&VE Laboratory, MSFC, by Systems Engineering Branch, Chrysler Corporation Space Division under Contract NAS 8-4016.

This volume describes subsystems and components within launch vehicle SA-8 that make up the RL10A-3 engine and hydraulic system. The information is presented in three sections: functional description, index of finding numbers, and mechanical schematics. The technical content reflects the functional system design information available on April 17, 1964.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1

FUNCTIONAL DESCRIPTION

1.1 INTRODUCTION

Six RL10A-3S liquid-propellant rocket engines, producing 90,000 pounds total thrust, power the S-IV stage of launch vehicle SA-8 after separation of the S-I and S-IV stages. Each engine develops 15,000 pounds of thrust in a space environment, and, should one engine fail, the remaining operable engines will provide sufficient thrust to accomplish the vehicle flight mission. The RL10A-3S engines have a multiple start capability; however, this feature will not be used on SA-8

The engines are gimbal mounted to the S-IV stage thrust structure in a circular pattern (figure 3-1) and are canted six degrees outward from the vehicle longitudinal axis. Each engine has an independent closed-loop hydraulic system that provides stage attitude and steering control by swiveling the engine at the gimbal mount. Engines 1, 2, 3, and 4 provide pitch, yaw, and roll control, however, engines 5 and 6 provide pitch and yaw control only.

The engines burn LOX (liquid oxygen) and LH_2 (liquid hydrogen) stored in a single, two-compartment propellant tank that supplies all six engines. The LH_2 container is pressurized with GH_2 (gaseous hydrogen) produced by the engines. The LOX container is pressurized with helium carried on the S-IV stage.

Schematic diagrams are provided in section 3 to supplement the functional description given in subsequent paragraphs. The index of finding numbers in section 2 provides physical and functional descriptions of components identified on system schematic diagrams to further supplement the system description.

1.2 RL10A-3 ENGINE SYSTEM

The RL10A-3S engine is the basic RL10-A3 engine modified for installation on the Saturn launch vehicle. In addition to the basic engine components, the RL10A-3S has a fuel tank pressurizing valve, a vent manifold, vibration damping support brackets, and special instrumentation mounted on the engine. The RL10A-3S also incorporates an electric motor on the LOX flow control valve for varying the LOX-to-LH_2 consumption ratio during engine operation.

The RL10A-3 engine is turbopump fed and the thrust chamber regeneratively cooled. The turbo-pump assembly is powered through a turbine and gearbox arrangement. GH_2, generated by passing LH_2 through tubes in the thrust-chamber wall, operates the turbine and is then burned with LOX in the engine combustion chamber to produce thrust. The hydrogen and oxygen propellant employed in the engine produces a specific impulse approximately 30-percent higher than liquid oxygen-kerosene engines.

1.2.1 <u>Engine System Component Description</u> - The majority of engine components are adequately described in the discussion on engine operation (paragraph 1.2.2) and in section 2 of this volume. Two of the more complex components, LOX Flow Control Valve E23 and Thrust Control Valve E8, are discussed in the following paragraphs.

1.2.1.1 LOX Flow Control Valve. LOX Flow Control Valve E23 is a multiple valve assembly that functions basically as a LOX flow regulator during the prestart chilldown and ignition phases of engine operation and as an oxidizer-to-fuel adjustment device during engine mainstage operation. During LOX chilldown, the regulator portion of the valve maintains a constant flow of LOX to the engine LOX injector and Igniter Oxidizer Valve E24 by passing a portion of the LOX around the adjustment device which is illustrated as a motorized control positioner in figure 3-1. A small portion of the chilldown LOX also flows through bleed passages in the adjustment device to cool the entire valve assembly. The combined LOX flow through LOX Flow Control Valve E23 also ensures that the proper amount of LOX will be present at the LOX injector for reliable engine ignition. After engine ignition, the control device portion of the valve is actuated by LOX pressure and opens to a preset position that establishes the proper oxidizer-to-fuel ratio for engine mainstage operation. During mainstage operation, the motorized control positioner portion of the valve acts as a propellant utilization device. Signals from liquid level sensors in the LOX and LH_2 containers control the operation of the motorized control positioner in Valve E23. The control positioner regulates LOX flow as required to achieve simultaneous LOX and LH_2 depletion. LOX flow control is adjusted during this operation to maintain the LOX to LH_2 consumption ratio between 4.5 to 1 and 5.5 to 1.

1.2.1.2 Thrust Control Valve. Thrust Control Valve E8 maintains engine thrust at a constant level by varying the amount of GH_2 that flows through a bypass around engine Turbine E7. To do this, the thrust control valve senses engine combustion chamber pressure as a direct function of engine thrust. If engine thrust increases above the acceptable limit, engine combustion chamber pressure also increases. The increase in combustion chamber pressure causes the thrust control valve to open and bypass a proportionate amount of GH_2 around the engine turbine through the bypass line. (See figure 3-1.) The resultant energy loss at the turbine causes turbine speed to decrease and the propellant pumps to slow down. The net result is that less propellant is induced into the engine system, causing engine thrust and resultant combustion chamber pressure to decrease. The decrease in combustion chamber pressure causes the thrust control valve to begin to close and thereby cancel the initial correction as engine thrust returns to the desired level.

Thrust Control Valve E8 is operated by GH_2 pressure bled from the main GH_2 discharge line upstream of Venturi E6. The venturi ensures that the pressure supplied to the thrust control valve is relatively constant and does not fluctuate with downstream pressures. Combustion chamber pressure is sensed and used for positioning the thrust control valve.

1.2.2 Engine System Operation - Engine operation consists of prestart chilldown, ignition, mainstage, and shutdown operations. All four operations are discussed in the order of occurrence.

1.2.2.1. Prestart Chilldown. The low temperature characteristics of the RL10A-3S engine propellant necessitates a prestart chilldown of the engine plumbing to temperature condition the engine components and prevent propellant pump cavitation. The chilldown operation consists of two separate sequences, LH_2 chilldown and LOX chilldown. LH_2 chilldown begins approximately 109 seconds after liftoff and LOX chilldown begins approximately 30 seconds later. Prior to LH_2 chilldown, the S-IV Stage hydrogen vent ducts are purged with helium to prevent a possible explosion. The LH_2 chilldown begins when the LH_2 prestart signal from the flight computer energizes prestart control Solenoid Valve E36. Helium at 455 psig from the S-IV stage control pressure system opens fuel inlet shutoff Pneumatic Valve E1. LH_2 under pressure from the S-IV stage LH_2 container flows through first stage fuel Pump E2, after which a portion is bled off through normally open interstage cooldown and Bleed Valve E3. The main flow of LH_2 continues through second stage fuel Pump E4 where a second portion is bled off through downstream cooldown and Bleed Valve E5. Both bleed portions are vented into the engine fuel vent collector manifold and dumped overboard through the S-IV stage hydrogen vent ducts. The major part of the LH_2 flow is dumped overboard after fuel pump chilldown because only a minor portion of the total flow is required for chilling down the remainder of the engine fuel system.

The remainder of the LH_2 chilldown flow passes through Orifice E43, the thrust chamber down tubes and up tubes, Venturi E6, and Turbine E7 to the face of main fuel shutoff Pneumatic Valve E9. Valve E9 is designed to allow a small amount of leakage into the engine fuel injector manifold. The LH_2 that leaks into the fuel injector manifold passes into Thrust Chamber E52.

The LOX chilldown is initiated when the first liquid level sensor on the S-I stage actuates, causing prestart control Solenoid Valve E45 to be energized. Helium at 455 psig from the S-IV stage control pressure system opens LOX inlet shutoff Pneumatic Valve E21. LOX under pressure from the S-IV stage LOX container flows to LOX Pump E22. LOX pressure at the pump inlet acts through the LOX sensing line to open Igniter Oxidizer Valve E24. LOX flow continues through the LOX pump to LOX Flow Control Valve E23 where it is bypassed around the control positioner by the regulator valve. A small portion of LOX also flows through the control positioner, cooling the entire valve assembly. (Refer to paragraph 1.2.1.1.) Both portions flow into the LOX discharge line where part of the flow is diverted through the igniter GOX (gaseous oxygen) pickup to the igniter oxidizer valve. This portion of LOX flow is delivered to the annular passage around the igniter center electrode in the form of GOX. The main LOX flow passes through the LOX injector manifold and injector nozzles into Thrust Chamber E52. LOX chilldown cools and minimizes thermal shock on the propellant injector plate prior to engine ignition. The cooling action also ensures that LOX instead of GOX will flow from the LOX injector at the time of engine ignition.

The LOX that is dumped into the engine thrust chamber during LOX chilldown is diluted by a GN_2 purge from the LOX/SOX (solid oxygen) disposal system as discussed in Volume V, Pneumatic Distribution System.

1.2.2.2 Ignition. Upon termination of the LOX and LH_2 prestart chilldown period, the engine ignition signal from the flight computer initiates the start sequence. Electrical power is supplied to Spark Igniter E53 and a two-second ignition period begins. Start control Solenoid Valve E38 is energized and 455-psig He (helium) from the control pressure system actuates interstage cooldown and Bleed Valve E3 and downstream cooldown and Bleed Valve E5 to the partially closed position. This allows an increased flow of LH_2 into Thrust Chamber E52 through main fuel shutoff Pneumatic Valve E9, which was actuated along with E3 and E5.

GOX flowing through the igniter GOX pickup and LH_2 flowing through the annular space around Spark Igniter E53 form a combustible mixture which is ignited by the spark igniter. Flame propagates throughout the combustion chamber and ignites the LOX and LH_2 flowing from the propellant injector to effect primary ignition.

Heat transferred through the inner walls of Thrust Chamber E52 vaporizes the LH_2 flowing in the thrust chamber tubes. The resultant high-pressure gases exit at the engine fuel outlet manifold and flow through Venturi E6 to Turbine E7. The high-pressure gases accelerate the turbine which in turn drives propellant Pumps E2, E4, and E22 through Gearbox E54. Once past the turbine, GH_2 flows through main fuel shutoff Pneumatic Valve E9 and the fuel injector manifold into the engine combustion chamber where it is burned with LOX. As the propellant pumps induce propellant into the engine system, pressure builds up in the LOX and LH_2 pump discharge lines. The pressure differential between the LOX pump inlet pressure, sensed through the LOX sensing line, and pump output pressure in the LOX discharge line causes LOX Flow Control Valve E23 to open to the preset position. This establishes the proper oxidizer-to-fuel ratio for engine operation. LOX flows through E23 into the engine through the LOX injector where it is burned with GH_2 to produce engine thrust. The LOX pressure buildup downstream of E23 is transmitted through the igniter GOX pickup to Igniter Oxidizer Valve E24, causing E24 to close and terminate the supply of GOX to the engine.

Pressure buildup in the fuel pump discharge line is sensed through the control fuel line by cooldown and Bleed Valves E3 and E5. When the first stage fuel pump discharge pressure reaches approximately 150 psia, E3 closes. E5 closes when second stage pump discharge pressure reaches approximately 330 psia. With both cooldown and bleed valves closed, the engine system receives a maximum amount of LH_2, causing engine thrust to build up to mainstage operation.

1.2.2.3 Mainstage Operation. The engines operate at full thrust for approximately 470 seconds. During this period, Thrust Control Valve E8 maintains the optimum thrust level and vehicle LOX consumption is regulated by LOX Flow Control Valve E23 to achieve simultaneous fuel and LOX depletion. (Refer to paragraph 1.2.1.1.)

Under ideal stage operating conditions, the engine will consume LOX and hydrogen at proportional rates that will cause simultaneous propellant depletion. However, in actual operation, variations in LOX and LH_2 container pressures, LH_2 flow, and LOX flow, make it necessary to directly sense propellant depletion rates and adjust LOX flow to ensure simultaneous propellant depletion. LOX and LH_2 liquid level sensors in the S-IV stage propellant containers send signals to an electronic propellant utilization bridge network that controls the position of the motorized control positioner in LOX Flow Control Valve E23. If LOX consumption is lagging proportional LH_2 consumption, the LOX and LH_2 tank liquid level sensors unbalance the propellant utilization bridge network, which opens the control positioner in proportion to the LOX consumption lag and increases LOX flow. If LOX consumption is leading proportional LH_2 consumption, the tank sensors unbalance the propellant utilization bridge network to close the control positioner, reducing LOX flow in proportion to the LOX consumption lead.

During engine operation, a portion of the GH_2 flow is tapped off the discharge line downstream of main fuel shutoff Pneumatic Valve E9 and is used to pressurize the LH_2 container in the S-IV stage propellant tank. The flow of GH_2 is controlled by Relief Valve E39 which was opened by fuel pressure during the engine start transient. During mainstage operation, E39 controls the flow of GH_2 to maintain LH_2 container pressurization.

A portion of LH_2 is tapped off of first stage fuel Pump E2, converted into GH_2, and is then used to cool Gearbox E54 and the propellant pump driveshafts. The GH_2 is vented through Relief Valve E51 into the GH_2 vent systems. Relief Valve E51 protects the gearbox from over-pressurization by opening between 17 and 25 psig. The gearbox also receives a continuous helium purge from the S-IV stage control pressure system. The purge enters the gearbox through Orifice E329 prior to the arrival of GH_2 and provides an inert atmosphere. This precludes the possibility of an explosion when GH_2 enters the gearbox. The same purge line from the control pressure system also provides a low-pressure purge to LOX flow control Valve E23 through Orifice E330. This purge keeps ice from forming on the control positioner gearshaft.

1.2.2.4 Shutdown. The time from ignition to engine shutdown is approximately 470 seconds. After approximately 450 seconds, engine cutoff is armed by a signal from the fuel level probe in the S-IV stage LH_2 container. When the first engine senses low thrust at Pressure Switches E55 and E56, a signal will deenergize Solenoid Valves E36, E38, and E45 on all six engines. Solenoid Valve E36 removes control pressure from LOX and fuel inlet shutoff Pneumatic Valves E1 and E21. This causes spring pressure to close the valves and shut off the flow of LOX and LH_2 to propellant Pumps E2, E4, and E22. Solenoid Valve E36 also removes control pressure to main fuel shutoff Pneumatic Valve E9 and cooldown and Bleed Valves E3 and E5. Pneumatic Valve E9 closes under spring pressure and cuts off the flow of GH_2 to the engine. GH_2 downstream of E9 vents through the fuel injector. E3 and E5 are actuated to the full open position by a combination of spring pressure and decreasing fuel pressure. This vents the fuel in the remainder of the engine fuel system into the fuel vent collector manifold.

The control positioner in LOX flow control Valve E23 closes as the LOX pump discharge pressure decays and spring force overcomes the LOX pump differential pressure acting on the control positioner. LOX and GOX, downstream of LOX inlet shutoff Pneumatic Valve E21, vent through the regulator portion of E23, into the engine LOX injector, and out through Thrust Chamber E52.

1.3 HYDRAULIC SYSTEM

Each of the six RL10A-3S engines has an independent, closed loop, high-pressure, hydraulic system to provide motive power for engine gimballing. Each system has an electric motor driven auxiliary pump for use in prelaunch operation and a turbine driven main pump for use in flight. The hydraulic system for the RL10A-3S engine is shown schematically in figure 3-2.

1.3.1 Hydraulic System Component Description - Major components of the hydraulic system for each engine include the main pump, the auxiliary pump, a sequence valve, a three-section accumulator assembly, a servo valve, a reservoir, and two servo-actuators. These components are described in the following paragraphs.

1.3.1.1 Main Pump. The turbine driven main Pump E61 is a nine-piston constant displacement pump that is driven at 12,500 rpm to develop a rated output of 1.07 gpm at 3100 psig. Design inlet pressure for the pump is 65 to 100 psig. The pump housing must be completely filled with hydraulic fluid before operation. The case drain is used for this purpose.

1.3.1.2 Auxiliary Pump. The electric motor-driven auxiliary Pump E96 is a nine-piston variable delivery pump that is driven at 11,300 rpm to develop a rated output of 0.5 gpm at 2950 psig. Design inlet pressure is 0 to 100 psig. The elctric motor develops about 1.4 horsepower on 115V, 3-phase power.

1.3.1.3 Sequence Valve. The two-position, solenoid-operated Sequence Valve E76 has separate solenoids for "on" and "off" functions. The sequence valve operates to the "on" position whenever there is a requirement for the high-pressure Accumulator Assembly E338 to reinforce or assist system operation. The sequence valve is operated by the S-IV stage guidance computer.

1.3.1.4 Accumulator Assembly. Accumulator Assembly E338 has three chambers: one for a high-pressure GN_2 precharge, one for high-pressure hydraulic fluid, and one for low-pressure hydraulic fluid. The GN_2 chamber is precharged to 2100 psig. The GN_2 precharge is compressed to 3000 psig by hydraulic fluid entering the high-pressure chamber of the accumulator whenever the auxiliary or main hydraulic pump is operating. The compressed GN_2 provides the motive force to expel hydraulic fluid from the high-pressure chamber whenever system operating pressure drops due to load demand. The same quantity of hydraulic fluid that was discharged from the high-pressure chamber will be returned to the low-pressure chamber to maintain system equilibrium.

The 49-to-1 ratio piston between the low- and high-pressure sections of the accumulator establishes system low-pressure at 61 psig. The low-pressure chamber stores hydraulic fluid at 61 psig and acts as a secondary reservoir. Potentiometer E73 monitors the position of the 49-to-1 ratio piston between the low-pressure and high-pressure chamber.

1.3.1.5 Servo Valve. Solenoid-operated Servo Valve E74 receives high-pressure hydraulic fluid at port C and routes this hydraulic fluid as required to cause the respective actuator piston to move in the programmed direction in accordance with signals from the guidance computer.

1.3.1.6 Reservoir. A single pressurized Reservoir Assembly E354, is provided to supply a steady input source for the hydraulic pumps. Reservoir operating pressure is approximately 61 psig.

1.3.1.7 Servoactuators. Two hydraulic servoactuator Assemblies, E110 and E341 supply movement to the gimbal-mounted engine to provide the necessary attitude and steering control. Each servoactuator is essentially a bi-directional cylinder in which direction of movement is determined by routing the high-pressure hydraulic fluid to one side of the piston or the other.

1.3.2 Hydraulic System Operation - Hydraulic system operation is divided into three distinct phases: system fill, prelaunch operation, and mission operation. Once filled, the system will normally be drained only as required for maintenance.

1.3.2.1 Hydraulic System Fill. An external source of GN_2 is connected to Nipple and Valve E70 and the Accumulator Assembly E338 is precharged to 2100 psig prior to adding hydraulic fluid to the system. High-pressure Transducer E82 in conjunction with Pressure Gage and Switch Assembly E71 monitors GN_2 precharge pressure. After the precharge has been established at the correct level, an external, 3000-psig high-pressure hydraulic supply is connected between high-pressure Quick-Disconnect Coupling E63 and low-pressure Quick-Disconnect Coupling E64. The externally pressurized hydraulic fluid enters the system and passes through Check Valve E347 and Filter E67. Check Valves E62 and E91 prevent hydraulic fluid from being forced through the pumps backward during the fill operation. The pressurized hydraulic fluid circulates through the system to completely fill all lines, valves, reservoir, servoactuators, and accumulator. Bypass Valve E90 on each servoactuator may be opened to assist in filling Servo Valve E74 and Servoactuator Assemblies E110 and E341. Bleed Valves E80, E84, E87, and E88 are used to vent any air that might be trapped in high points of the system. Relief Valve E89 provides overpressure protection. When the relief valve operates, excess pressure is relieved to the reservoir return line. As the system fills, pressure in low-pressure Cylinder Assembly E108 of the accumulator rises. When this pressure reaches 65 psig, Relief Valve E68 opens completing the low-pressure return path to the external hydraulic supply through Quick-Disconnect Coupling E64. Programming the RL10A-3S engine servoactuators for movement during the fill procedure aids in fluid circulation.

1.3.2.2 Prelaunch Operation. Motor-driven auxiliary Pump E96 runs during prelaunch operation and checkout. The pump draws hydraulic fluid from Reservoir E354 through Filter E92. Output from the pump passes through Check Valve E93, Filter E94, Check Valve E91, Filter E67 and Check Valve E78 to charge high-pressure Cylinder Assembly E109 of Accumulator Assembly E338 to 2950 psig. If engine motion is programmed, hydraulic fluid flows through Check Valve E77 and Manual Valves E112 to Servo Valves E74 where the fluid is routed to Servoactuator Assemblies E110 and E341 as required to produce the programmed motion. At a programmed time prior to liftoff, Sequence Valve E76 is closed trapping high-pressure hydraulic fluid in the accumulator and the auxiliary pump is shut off. Temperature Transducer E86 monitors reservoir temperature. Should reservoir temperature exceed 175 F, Thermal Switch E83 shuts off the auxiliary pump.

Bypass Manual Valve E90 may be opened any time auxiliary Pump E96 is not operating to permit manual positioning of the RL10A-3S engine.

1.3.2.3 Mission Operation. Just prior to RL10A-3S engine ignition, Sequence Valve E76 is opened and the high-pressure hydraulic fluid stored in Accumulator Assembly E338 is used to pre-position the engine. This centers the thrust vectors of all of the RL10A-3S engines on the vehicle centerline and eliminates the possibility of vehicle instability during the initial moments after engine firing.

As the RL10A-3S engine builds up speed, main Pump E61 draws hydraulic fluid from Reservoir E354 and forces the fluid at 3000 psig into the system through Check Valve E62 and Filter E67. When engine movement is programmed, hydraulic fluid flows through Check Valve E77 and Manual Valves E112 to port C of Servo Valve E74. The servo valve determines the direction and amount of hydraulic fluid flow to move either Servoactuator Assemblies E110 or E341 the programmed amount. For a downward motion of the piston, fluid flows from C to D in the servo valve and return flow is from the servoactuator assembly to port A and through the servo valve to port B. The return flow is then through Filter E85 and Manual Valve E112 to Reservoir E354. If programmed motion causes system pressure to fall, Sequence Valve E76 opens and accumulator GN_2 pressure forces hydraulic fluid from the high-pressure Cylinder Assembly E109 into the system to counterbalance the pressure drop. The reduction in fluid in the high-pressure cylinder assembly and the resultant pressure drop causes the 49-to-1 ratio piston between the high-pressure cylinder assembly and Low-Pressure Cylinder Assembly E108 to move thereby causing the same quantity of hydraulic fluid to be drawn into the low-pressure cylinder assembly. When system demand has been satisfied, the high-pressure cylinder assembly again accepts hydraulic fluid at 3000 psig and the low-pressure cylinder assembly discharges a like amount of fluid to the system thereby maintaining system equilibrium. Should pressure rise to more than 65 psig in the low-pressure portion of the system due to pressure and temperature changes, Relief Valve E68 will open venting excess fluid through series Relief Valve E66 to the outside. When system pressure returns to normal, the venting action ceases.

System output pressure is monitored by Pressure Transducer E349. System return pressure is monitored by Pressure Transducer E336. System return temperature is monitored by Temperature Transducer E340. Differential pressure Transducer E95 monitors the differential pressure across the pistons of Servoactuator Assemblies E110 and E341 during flight. Feedback Potentiometers E72 monitor the position of the piston in the servoactuator assemblies.

SECTION 2

INDEX OF FINDING NUMBERS

This section contains an alpha-numerical list, by finding number, of RL10A-3 engine and hydraulic system components that function during a prelaunch countdown, during vehicle flight, or in the event of a launch abort. The finding numbers listed identify components on system schematic diagrams provided in section 3. Additional columns in the index of finding numbers provide such pertinent information as component description and function, part number, and the supplier's name and part number. A break will occur in the alpha-numeric sequence of finding numbers when a component or component series is non-functional during the countdown, functional only in the event of a malfunction, functional only during maintenance operation, or part of another functional system.

The letter prefix of a finding number identifies the component with either the launch complex or an area of the launch vehicle. The area associated with each prefix is noted below.

FINDING NUMBER PREFIX	DESIGNATED AREA
A	Launch complex
B	S-I stage
E	S-IV stage
G	Instrument unit
H	Payload

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E1	6	Valve, Pneumatic	2-position, NC; fuel inlet shutoff	Pratt & Whitney Aircraft Div. P/N 2053427		
E2	6	Pump	0 to 100 psig inlet press. -425 to +110 F opr press., first stage LH_2	Pratt & Whitney Aircraft Div. P/N 2046928		
E3	6	Valve, Bleed	3-position, N.O.; interstage cooldown and bleed	Pratt & Whitney Aircraft Div. P/N 2062086		
E4	6	Pump	0 to 100 psig discharge press. -425 to +110 F opr temp; second stage LH_2	Pratt & Whitney Aircraft Div. P/N 2029676		
E5	6	Valve, Bleed	3-position, N.O.; downstream cooldown and bleed	Pratt & Whitney Air-Div. P/N 2062087		
E6	6	Venturi	1.156 in. throat dia, 0 to 1000 psig opr press.; convergent - divergent	Pratt & Whitney Air-Div. P/N 2053239		
E7	6	Turbine	529 hp at 28,400 rpm; 2-stage, gas-operated; impulse	Pratt & Whitney Aircraft Div. P/N 2037934		
E8	6	Valve, Thrust Control	Servo-operated, variable position	Pratt & Whitney Air-Div. P/N 2069870		
E9	6	Valve, Pneumatic	5.85 lb/sec flow rate, 2-position, N.C.; main fuel shutoff	Pratt & Whitney Air-Div. P/N 2064010		
E10 through E20 are not functionally applicable to this system.						
E21	6	Valve, Pneumatic	2-position, NC.; LOX inlet shutoff	Pratt & Whitney Air-Div. P/N 2053426		
E22	6	Pump	185 gpm at 11,400 rpm nom; 49 psia inlet press, 484 psia discharge, LOX	Pratt & Whitney Air-Div. P/N 2054182		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E23-1	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt &Whitney Aircraft Div. P/N 2059356		401A3A2
E23-2	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt & Whitney Aircraft Div. P/N 2059356		402A3A2
E23-3	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt &Whitney Aircraft Div. P/N 2059356		403A3A2
E24-4	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt & Whitney Aircraft Div. P/N 2059356		404A3A2
E23-5	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt & Whitney Aircraft Div. P/N 2059356		405A3A2
E23-6	1	Valve, Flow Control	464 psia opr press., 29.3 lb/sec flow rate; LOX	Pratt & Whitney Aircraft Div. P/N 2059356		406A3A2
E24	1	Valve, Igniter Oxidizer	NC, GOX supply control	Pratt &Whitney Aircraft Div. P/N 2056226		
E25 through E35 are not functionally applicable to this system.						
E36-1	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		401A3L1
E36-2	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt &Whitney Aircraft Div. P/N 2059413		402A3L1
E36-3	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt &Whitney Aircraft Div. P/N 2059413		403A3L1
E36-4	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		404A3L1

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E36-5	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		405A3L1
E36-6	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; prestart control	Pratt &Whitney Aircraft Div. P/N 2059413		406A3L1
E37 is not functionally applicable to this system.						
E38-1	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt &Whitney Aircraft Div. P/N 2059413		401A3L2
E38-2	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt & Whitney Aircraft Div. P/N 2059413		402A3L2
E38-3	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt & Whitney Aircraft Div. P/N 2059413		403A3L2
E38-4	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt & Whitney Aircraft Div. P/N 2059413		404A3L2
E38-5	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt & Whitney Aircraft Div. P/N 2059413		405A3L2
E38-6	1	Valve, Solenoid	3-way, 2-position, 450 (±50) psia He flow; start control	Pratt & Whitney Aircraft Div. P/N 2059413		406A3L2
E39	6	Valve, Relief	2-way, fuel tank pressurizing	Pratt & Whitney Aircraft Div. P/N 2073293		
E40 through E42 are not functionally applicable to this system.						
E43	6	Orifice	0.813 in. dia.	Pratt & Whitney Aircraft Div. part of P/N 2036709		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E44 is not functionally applicable to this system.						
E45-1	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		401A3L3
E45-2	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		402A3L3
E45-3	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		403A3L3
E45-4	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		404A3L3
E45-5	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control	Pratt & Whitney Aircraft Div. P/N 2059413		405A3L3
E45-6	1	Valve, Solenoid	3-way, 2-position, 450 (± 50) psia He flow; prestart control.	Pratt & Whitney Aircraft Div. P/N 2059413		406A3L3
E46 through E50 are not functionally applicable to this system.						
E51	6	Valve, Relief	17 to 25 psig opr press., turbine cooldown inlet	Pratt & Whitney Aircraft Div. P/N 2030226		
E52	6	Thrust Chamber	300 psia nom combustion press.	Pratt & Whitney Aircraft Div. P/N 2053649		
E53	6	Igniter, Spark	20 sparks/sec, center electrode, air-gap type	Pratt & Whitney Aircraft Div. P/N 30092		
E54	6	Gearbox	3-gear, idler-type drive; GH_2 lubricated	Pratt & Whitney Aircraft Div. P/N 2041739		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E55-1	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		401A3S3
E55-2	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		402A3S3
E55-3	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		403A3S3
E55-4	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		404A3S3
E55-5	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		405A3S3
E55-6	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		406A3S3
E56-1	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		401A3S4
E56-2	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		402A3S4
E56-3	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		403A3S4
E56-4	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		404A3S4
E56-5	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		405A3S4
E56-6	1	Switch, Pressure	Actuates at 307 (±5) psia, deactuates at 262 (±10) psia	Douglas Aircraft Co. Inc. P/N 7871665-1		406A3S4

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E57 through E60 are not functionally applicable to this system.						
E61	6	Pump	1.07 gpm at 12,500 rpm nom; 9-piston, turbine-driven	Vickers Inc. P/N PF001R006C		
E62	6	Valve, Check	3000 psig nom opr press., 2 to 8 psig cracking press.	Parker Aircraft Co. P/N H61C0665		
E63	6	Coupling, Quick-Disconnect	High-pressure	E. B. Wiggins Co. P/N 26005D175D4		
E64	6	Coupling, Quick-Disconnect	Return line	E. B. Wiggins Co. P/N 26005D175D6		
E65	6	Manifold and Housing Assembly	3100 psig nom. opr. press., main pump	Douglas Aircraft Co. Inc. P/N 1A39757-1		
E66	6	Valve, Relief	1.2 gpm flowrate; cracks at 110 psig max, closes at 80 psig min.	Bertea Products, Inc. P/N 65945		
E67	6	Filter	2.0 gpm flowrate; high press. type w/check valve	Bertea Products Inc. P/N 65950		
E68	6	Valve, Relief	1.2 gpm flowrate; cracks at 110 psig max, closes at 80 psig min	Bertea Products Inc. P/N 65945		
E69	6	Actuator Assembly	Hydraulic, consists of E338 and E341	Moog Servocontrols Inc. P/N 17-172		
E70	6	Nipple and Valve	High-press. GN_2 fill	P/N MS28889-1		
E71	6	Pressure Gage and Switch Assembly	3,000 psia nom. opr. press., actuates at 2870 ($\pm$40) psig deactuates at 2770 ($\pm$40) psig	Glassco Instruments Co. P/N 50014		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E72	12	Potentiometer, Feedback		Moog Servocontrols Inc. P/N 062-12526		
E73	6	Potentiometer	Piston-position	Bertea Products Inc. P/N 65940		
E74	12	Valve, Servo	Hydraulic	Moog Servocontrols Inc. P/N 010-28146		
E75	12	Valve, Relief		Moog Servocontrols Inc. P/N 023-12275		
E76	6	Valve, Sequence	2-position, solenoid operated	Bertea Products Inc. Part of P/N 65900		
E77	6	Valve, Check	40 to 50 psig cracking press.	Bertea Products Inc. P/N 65921-1		
E78	6	Valve, Check	2 to 8 psig cracking press.	Bertea Products Inc. P/N 65920-1		
E79	6	Actuator Assembly	Hydraulic, Consists of E110 and E354	Moog Servocontrols Inc. P/N 17-173		
E80	6	Valve, Bleed		Fluid Regulators Inc. P/N 7579-S	60C27699	
E81	6	Valve, Bleed		Fluid Regulators Inc. P/N 7579-S	60C27699	
E82	6	Transducer	0 to 3500 psig range; GN_2 press. monitoring	Douglas Aircraft Co. Inc. P/N 7870467-561		
E83	6	Switch, Thermal	Opens at 160 (±8) F, closes at 140 (±10) F	Texas Instruments Inc. P/N 21428		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E84	12	Valve Bleed		Fluid Regulators Inc. P/N 7579S	60C27699	
E85	12	Filter	5 micron, 1.0 gpm, at 3000 psig	Moog Servocontrols Inc. P/N 071-12536		
E86	6	Transducer, Temperature	-40 to +350 F, dual element probe	Rosemount Engineering Co. P/N 150CG		
E87	12	Valve, Bleed	Servoactuator	Fluid Regulators Inc. P/N 7579-S	60C27699	
E88	12	Valve, Bleed	Servoactuator	Fluid Regulators Inc. P/N 7579-S	60C27699	
E89	6	Valve, Relief	1.2 gpm at 3500 psig max, reseat at 3100 psig max	Pneudraulics Inc. P/N 1577		
E90	12	Valve, Manual	2-way, 2-position; bypass	Moog Servocontrols Inc. P/N 032-12636		
E91	6	Valve, Check		Bertea Products Inc. P/N 59500		
E92	6	Filter	5 micron, 2.0 gpm at 3000 psig	Purolator Products Inc. P/N 7501510		
E93	6	Valve, Check	3000 psig nominal operating press	Parker Aircraft Co. P/N H61C0665		
E94	6	Filter	5 micron, 2.0 gpm at 3000 psig	Purolator Products Inc. P/N 7501509		
E95	12	Transducer	3000 to 5000 psig, differ-ential press.	Travis Engineering P/N 4-107-5000D		

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E96	6	Pump	2950 psig nom opr press., 0.5 gpm at 11,300 rpm; 9-piston, motor-driven	Vickers Inc. P/N AA19563-E		
E97 through E107 are not functionally applicable to this system.						
E108	6	Cylinder Assembly	Low-pressure accumulator	Bertea Products Inc. P/N 65903-1		
E109	6	Cylinder Assembly	High-pressure accumulator	Bertea Products Inc. P/N 65901-1		
E110	6	Servoactuator, Assembly	Hyddaulic, part of E79; consists of: E72, E74, E85, E90, E112	Moog Servocontrols Inc. P/N 010-12717		
E111	6	Manifold Assembly	Auxiliary pump, consists of E91, E92, and E94	Douglas Aircraft Co. Inc. P/N 1A48621-1		
E112	12	Valve, Manual	4-way, 2-piston, N.O.; prefiltration	Moog Servocontrols Inc. P/N 032-12637		
E113 through E328 are not functionally applicable to this system.						
E329	6	Orifice	260 scim He, engine gearbox press.	Douglas Aircraft Co. Inc. P/N 1A19281-1		
E330	6	Orifice	260 scim He, LOX flow control press.	Douglas Aircraft Co. Inc. P/N 1A19281-1		
E331-1	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		401A3S6
E331-2	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		402A3S6

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E331-3	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		403A3S6
E331-4	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		404A3S6
E331-5	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		405A3S6
E331-6	1	Switch, Pressure	LOX inlet shutoff valve control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		406A3S6
E332 is not functionally applicable to this system.						
E333	6	Pad, Accessory Dirve	Main hydraulic pump	Pratt &Whitney Aircraft Div. Part of P/N 2041739		
E334 and E335 are not functionally applicable to this system.						
E336	6	Transducer, Pressure	0 to 300 psig; low-pressure hydraulic fluid monitoring	Bourns Laboratories Inc. P/N 2004201903		
E337-1	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		401A3S1
E337-2	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. 2057681		402A3S1
E337-3	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		403A3S1
E337-4	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		404A3S1

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E337-5	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		405A3S1
E337-6	1	Switch, Pressure	LH_2 prestart control line monitoring	Pratt & Whitney Aircraft Div. P/N 2057681		405A3S1
E338	6	Accumulator Assembly	Part of E69 consists of: E66, E67, E68, E73, E76, E77, E78, E89, E108, E109, E347	Bertea Products Inc. P/N 65900		
E339-1	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		401A3S2
E339-2	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		403A3S2
E339-3	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		403A3S2
E339-4	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		404A3S2
A339-5	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		405A3S2
A339-6	1	Switch, Pressure	Main fuel valve control line monitoring	Pratt & Whitney Aircraft P/N 2057681		406A3S2
A340	6	Transducer, Temperature	-40 to 350 F, dual element probe	Rosemount Engineering Co. P/N 150CG		
E341	6	Servoactuator Assembly	Hydraulic, part of E69: consistss of E72, E74, E85, E90, E112	Moog Servocontrols Inc. P/N 010-12717		
E342 through E346 are not functionally applicable to this system.						

Finding Number	Reqd	Component	Remarks	Vendor	Drawing Number	Elec. Sym.
E347	6	Valve, Check	2 to 8 psig cracking press. high-press. Hydraulic fill	Bertea Products Inc, P/N 65920-1		
E348 is not functionally applicable to this system.						
E349	6	Transducer	Main pump output	Douglas Aircraft Co. Inc. P/N 7870467-561		
E350 through E353 are not functionally applicable to this system.						
E354	6	Reservoir Assembly	Hydraulic fluid, part of E79	Bertea Products Inc. P/N 66000		

SECTION 3

MECHANICAL SCHEMATICS

This section contains mechanical schematics that reflect all of the components involved in the functional operation of the RL10A-3 engine and hydraulic system. For a definition of the mechanical symbols used, see MSFC-STD-162A.

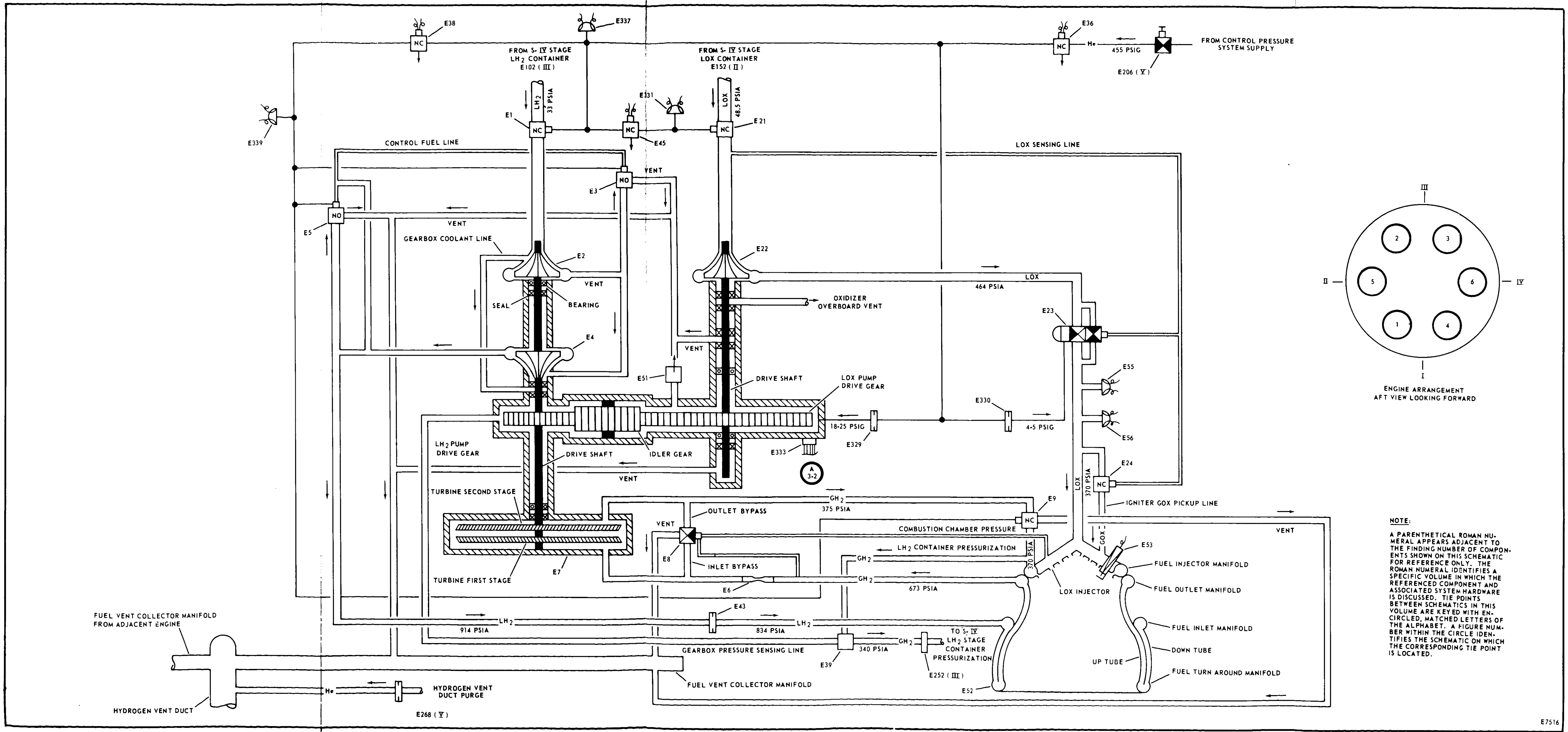

Figure 3-1. RL10A-3 Engine - Schematic Diagram

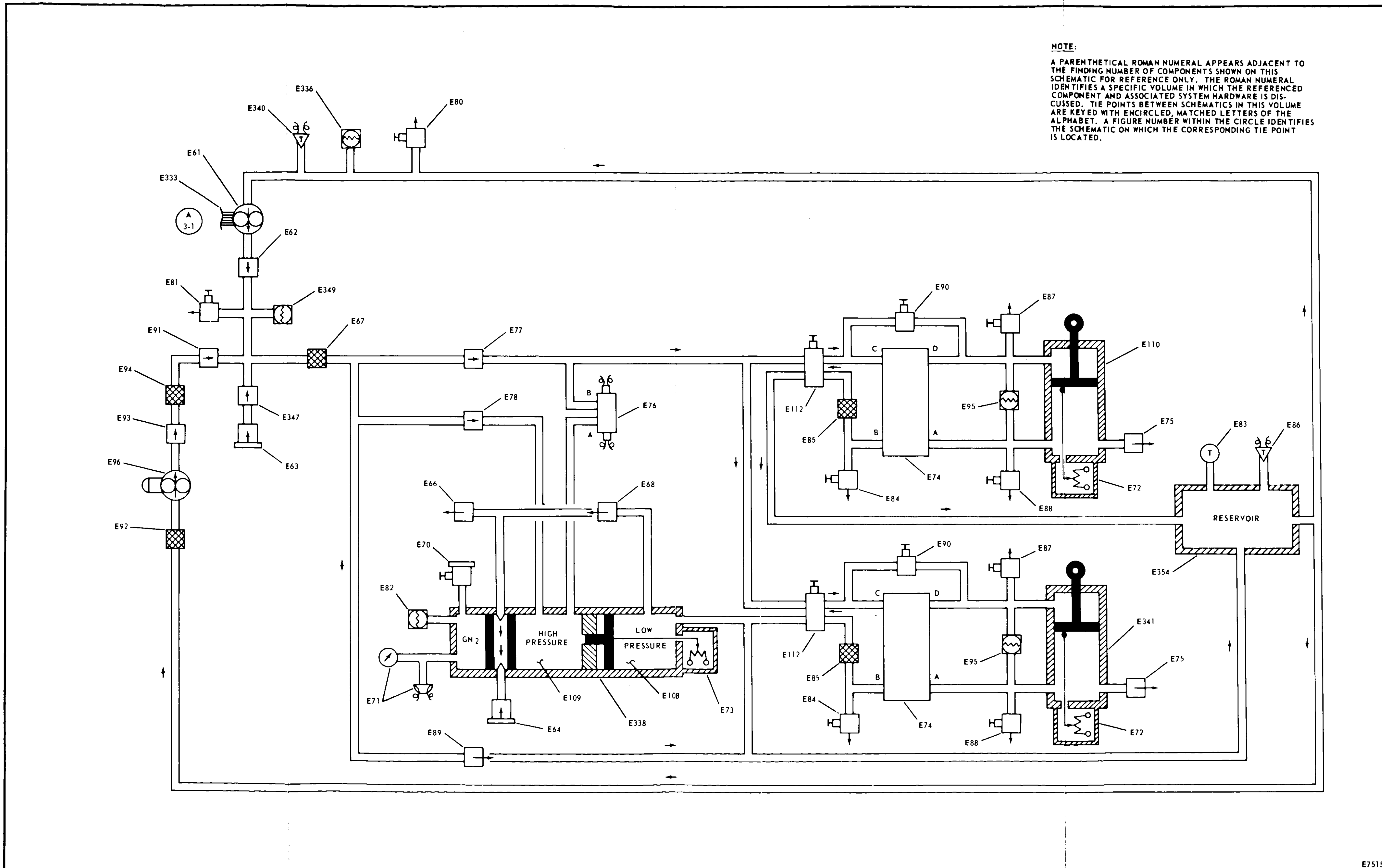

Figure 3-2. RL10A-3 Engine Hydraulic System - Schematic Diagram

APPENDIX A

LISTING OF LAUNCH VEHICLE SA-8 AND LAUNCH COMPLEX 37B VOLUMES

Volume	Title
I	RP-1 Fuel System
II	LOX System
III	LH_2 System
IV	Nitrogen and Helium Storage Facility
V	Pneumatic Distribution System
VI	Environmental Conditioning Systems
VII	Launch Pad Accessories
VIII	H-1 Engine and Hydraulic System
IX	RL10A-3 Engine and Hydraulic System
X	Separation and Flight Termination Systems